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A FLUIDIC GENERATOR AS AN ENVIRONMENTAL AND SAFETY DEVICE FOR T--ETC(U)

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A Fluidic Generator as an Environmental and Safety Device for the SUU-53/A Cartridge Dispenser

March 1977

U.S. Army Materiel Development and Readiness Command
HARRY DIAMOND LABORATORIES
Adelphi, Maryland 20783

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A fluidic generator, when mounted in an SUU-53/A cartridge dispenser, allows the pilot to fire cartridges only when the aircraft is in flight and has reached a velocity of 170 indicated airspeed in knots (KIAS) for all flight altitudes; below 140 KIAS the device is inoperative; this inoperativeness makes the dispenser safe. The fluidic generator as an environmental safety and arming device was flight tested at subsonic and supersonic speeds over

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and successfully passed all Military Standards qualifications, as described in Naval Weapons Center Regulation 4533-31-72. In May 1975, the device was judged fit for unlimited production by the Naval Weapons Systems Explosive Safety Review Board, Washington, DC.

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1. INTRODUCTION

A fluidic environmental sensor was developed to increase safety to SUU-53/A cold cloud cartridge dispensers aboard aircraft. The sensor, known as Airspeed Actuated Safety and Arming Device (AASAD) SWU-52/A, consists of a fluidic generator and a firing circuit. The fluidic generator converts ram air during aircraft flight into electrical energy. The energy is used to activate the gate of a silicon-controlled rectifier (SCR) in the firing circuit that channels the firing voltage from the aircraft to the dispenser intervalometer to eject catalyst generator cartridges. Sufficient energy is emitted from the fluidic generator to activate the firing circuit when the aircraft has reached a speed of 170 indicated air speed in knots (KIAS) for all flight altitudes. At speeds below 140 KIAS (e.g., when the aircraft is on the ground), the firing circuit remains inoperative. At speeds between 140 and 170, the device is intermittent at some altitudes. In general, no cartridges can be fired accidentally while the aircraft is on the ground or on the deck of a carrier.

This report describes the operation of the fluidic generator and the firing circuit of the AASAD. It summarizes flight and environmental testing of the dispenser and the fluidic generator reliability analysis conducted by the Naval Weapons Center (NWC), China Lake, CA.

2. DISPENSER DESCRIPTION

The dispenser is a store to carry and fire catalyst generator cartridges from attack, fighter, and patrol aircraft. The dispenser (fig. 1, 2) is constructed of metal, 72 in. (1.82 cm) long, 12-1/2 in. (31.3 cm) high, and 8-1/2 in. (21.3 cm) wide. It weighs 100 lb (45.4 kg) empty and 150 lb (68.6 kg) loaded.

Figure 1. The SUU-53/A cartridge dispenser.

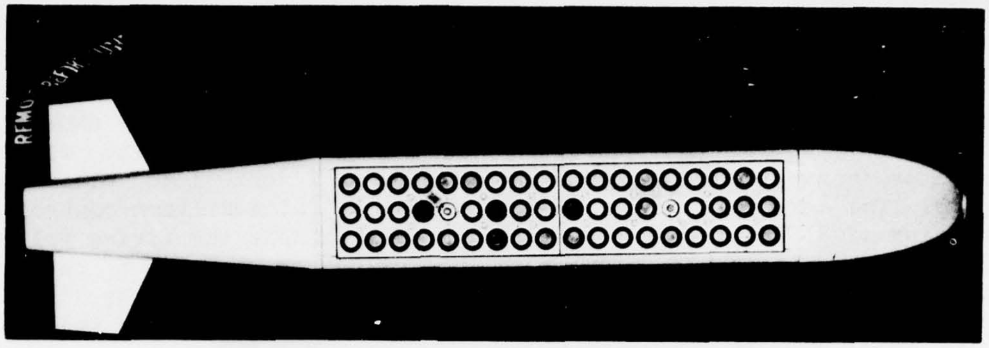

Figure 2. Bottom view of SUU-53/A cartridge dispenser with full load of cartridges.

The major components of the dispenser (fig. 3) are the nose section with the AASAD; the body section with the cartridge ejector and two cartridge retainers; and the aft section with the intervalometer, umbilical connector with radio-frequency (rf) filter, and manual safety switch. The AASAD consists of a fluidic generator, which with a solid-state circuit senses aircraft speed and completes the firing circuit in the dispenser when the aircraft reaches a nominal indicated air speed of 160 KIAS. The nose section reduces drag. Through the body section, the main structural member, loads are transferred to the aircraft. In the cartridge ejector are 52 electrical firing-pin assemblies, and attached to it are the cartridge retainers. The aft section reduces drag. The intervalometer distributes the firing pulse to the appropriate round to be fired. The umbilical connector mates the dispenser electrically with the aircraft rocket firing system. Until loaded with catalyst generator catridges, the dispenser contains no explosive components. It may be carried by either subsonic or supersonic aircraft. A typical installation is shown in figure 4.

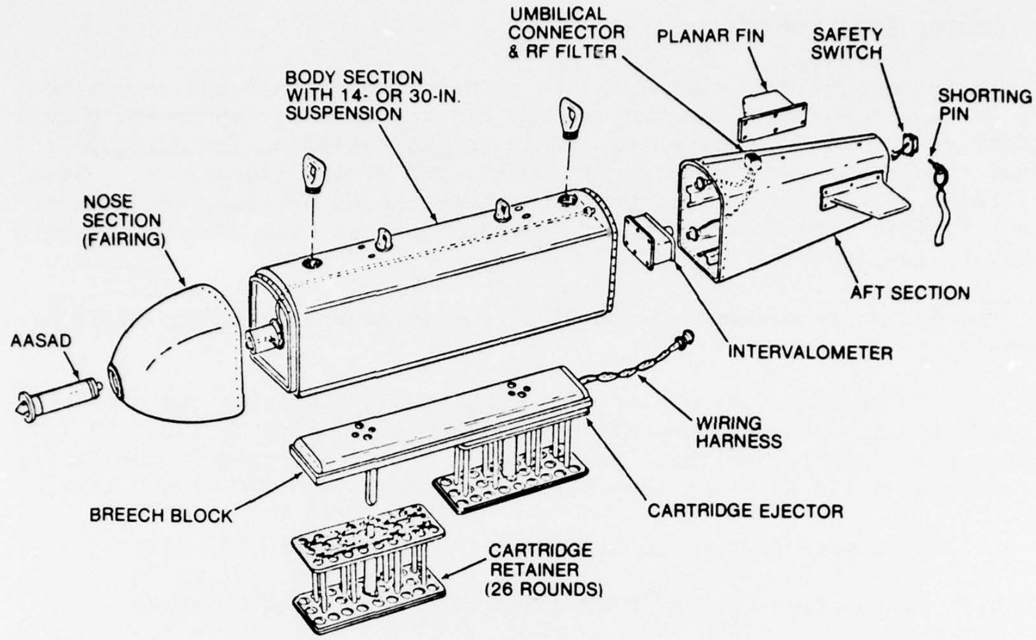

Figure 3. Exploded view of SUU-53/A cartridge dispenser.

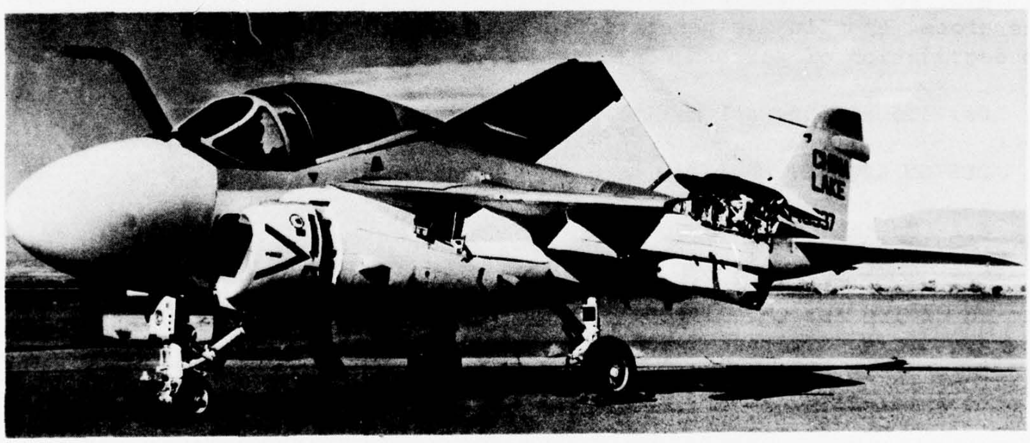

Figure 4. The SUU-53/A cartridge dispenser installed on A-4 aircraft.

3. DESIGN REQUIREMENTS OF AASAD

In September 1972, the Naval Air Command established the requirement for an environmental sensing safety device, in addition to the manual safety switch for the dispenser. This ruling satisfied the MIL-STD-1455 requirement[1] of two independent safety and arming signatures. After reviewing different types of environmental-sensing devices, NWC selected the fluidic generator, under development at the Harry Diamond Laboratories (HDL).

The design requirements for the fluidic generator in the AASAD are these:

a. To provide an electrical output which completes the dispenser firing circuit when the aircraft has reached a velocity of 170 KIAS (The arming requirements are that no voltage be transmitted to the firing circuit below 140 KIAS and that all arming occur from 170 to 600 KIAS.)

b. To function up to an altitude of 35,000 ft (10,500 m)

c. To function within 50 ms after reaching arming velocity

d. Its operation to be unaffected by flight through rain, dust, and icing conditions, since the AASAD will be in the dispenser and thereby subject to all aircraft flight environments

e. To be reusable for at least one hundred 2-hr flight missions; therefore, the fluidic generator to continuously operate for 200 hr with no degradation of performance

f. To satisfy all military environmental testing standards

4. DESIGN CONCEPT OF AASAD

4.1 Operational Concept

The AASAD employs a fluidic generator as a velocity-actuated arming device for the dispenser. The fluidic generator converts ram-air energy during aircraft flight into electrical energy. The energy is in the form of an alternating voltage which is proportional to the velocity of the inlet air.

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[1]*Military Standard Dispenser and Sub-Munition, Air Delivered, Safety Design and Safety Qualification Criteria for MIL-STD-1455 (August 1971).*

The basic operational concept of the AASAD is illustrated in the block diagram shown in figure 5. The voltage output from the generator, after rectification, activates a normally open SCR. In the open state, the SCR prevents completion of the firing circuit in the dispenser. The SCR is closed only if (1) the aircraft has reached a flight velocity of 170 KIAS and (2) a firing pulse from the aircraft (pilot) is present.

Hence, to eject cartridges from the dispenser requires coincidence of power provided by two independent sources: (1) the fluidic generator and (2) the aircraft power supply (28 Vdc) transmitted by the pilot's firing switch. The fluidic generator generates sufficient energy to activate the SCR only when the aircraft has reached the preset minimum arming velocity. When the aircraft flies below this velocity, or is on the ground, the firing circuit remains open. Thus, the dispenser is safe from accidental ground firing. The AASAD concept thus satisfies MIL-STD-1455. The fluidic generator and the AASAD firing circuit are described in the following sections.

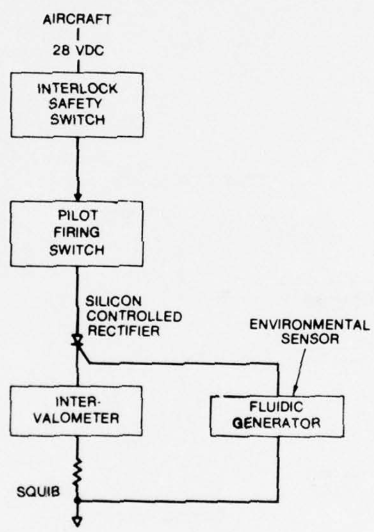

Figure 5. Operational concept of airspeed actuated safety and arming device.

4.2 Fluidic Generator

The fluidic generator[2] (fig. 6) converts pneumatic energy (ram air) during flight into electrical energy in three steps: (1) pneumatic-to-acoustical, (2) acoustical-to-mechanical, and (3) mechanical-to-electrical. The pneumatic-to-acoustical transformation is accomplished by a fluid oscillator of the ring-tone type (fig. 7). Air passes through the annular nozzle into a cone-shaped cavity whose opening is concentric with the nozzle. When the annular jet impinges on the leading edge of the cavity, it sets the edge into acoustic oscillations. Within the cavity, air pulsation triggers a metal diaphragm at resonance (acoustical-to-mechanical transformation). The vibrations of the diaphragm are transmitted by a connecting rod to a reed that is between the poles of a permanent magnet. The vibrations of the reed thus produce an electromagnetic frequency (emf) in a coil around it. This emf is the end of the mechanical-to-electrical transformation. The generator operates at the mechanical resonant frequency of the diaphragm. The diaphragm has been heat treated so that its frequency is insensitive to temperature over the military specifications.

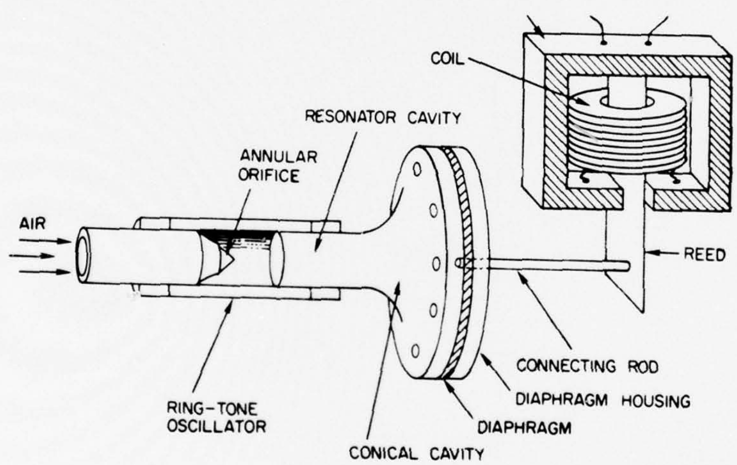

Figure 6. Fluidic generator with ring-tone oscillator.

[2]*C. J. Campagnuolo, The Fluidic Generator, Harry Diamond Laboratories TR-1328 (September 1966).*

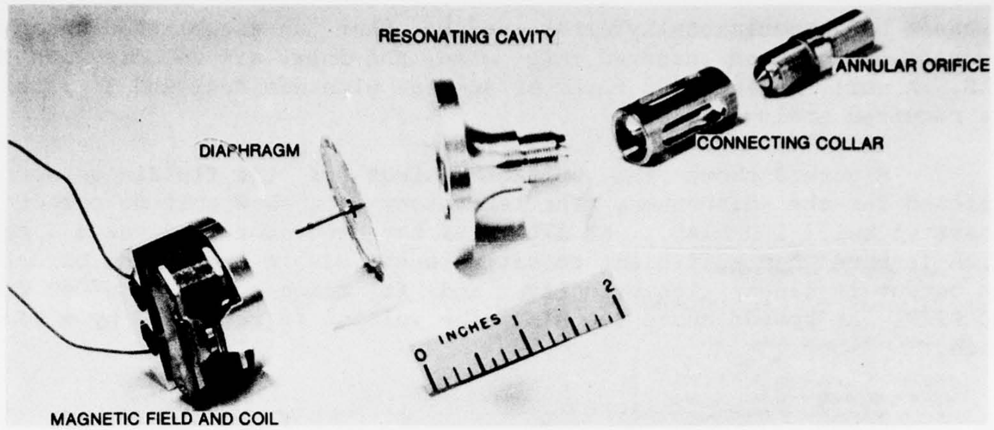

Figure 7. Fluidic-generator components.

For use as an environmental safety and velocity sensing device for the dispenser, the generator is required (1) to provide an electrical output proportional to the inlet air velocity and (2) to generate sufficient energy (3.5 V) to activate the SCR in the firing circuit only when the aircraft reaches a nominal indicated air speed of 170 KIAS. Any voltage generated below 140 KIAS is automatically suppressed by the electronic circuit (see sect. 4.2).

The first design requirement, the proportional relationship between inlet air velocity and electrical output, was achieved experimentally. Laboratory studies indicated that by adjusting the concentricity of the annular orifice in the nozzle with respect to the cavity opening diameter, input air pressure was made directly proportional to output acoustic amplitude. Specifically, the leading edge of the circular opening was at the geometric center of the annular orifice. This linear pneumatic-to-acoustical transformation was retained through the other transformation processes, and a velocity sensing generator resulted.

The second design requirement was satisfied by setting the operating threshold pressure (velocity) of the acoustic resonator at a level corresponding to air velocity of 170 KIAS. Below this velocity, no resonant acoustic oscillation takes place. The operating threshold pressure of the generator is governed by the distance between the nozzle and the cavity opening entrance. Experiment indicated that, in general, the threshold pressure level increases with increasing nozzle-to-cavity distance. To satisfy the preset arming velocity requirements, a

distance was experimentally determined so that an established resonant acoustic oscillation occurred only when the inlet air velocity was 170 KIAS. A coil having 1400 turns of 36-gage wire was designed to provide the required arming voltage.

Figure 8 shows the voltage output of the fluidic generator designed for the dispenser. The laboratory data show that no output is generated below 150 KIAS. At 170 KIAS, the generator produces 8 V rms, which is more than sufficient to activate the SCR in the firing circuit. The output is linear with velocity, and it reaches a level of 40 V at 400 KIAS. At speeds above 400 KIAS, the voltage is regulated by a Zener diode.

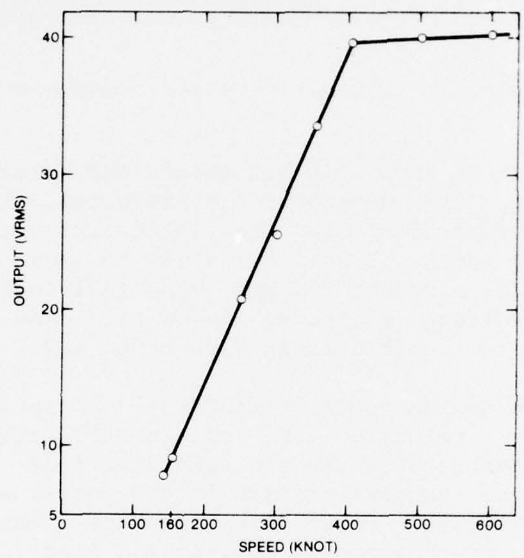

Figure 8. Fluidic-generator output voltage versus inlet air velocity.

To ensure proper functioning under adverse environments, the fluidic generator is mounted in a protective housing that contains an ice deflector and a two-stage water-air separator. The housing (fig. 9) is designed to remove solid impurities and to prevent liquid and ice particles from entering the generator, with minimum ram pressure loss. The housing is mounted inside the nose section of the dispenser. The ice deflector in the housing is exposed to the air stream. During flight, the bell-shaped (or onion-shaped) deflector causes sand particles or other debris in the ram air to be deflected from the housing. In flights through icing conditions, ice builds up in the

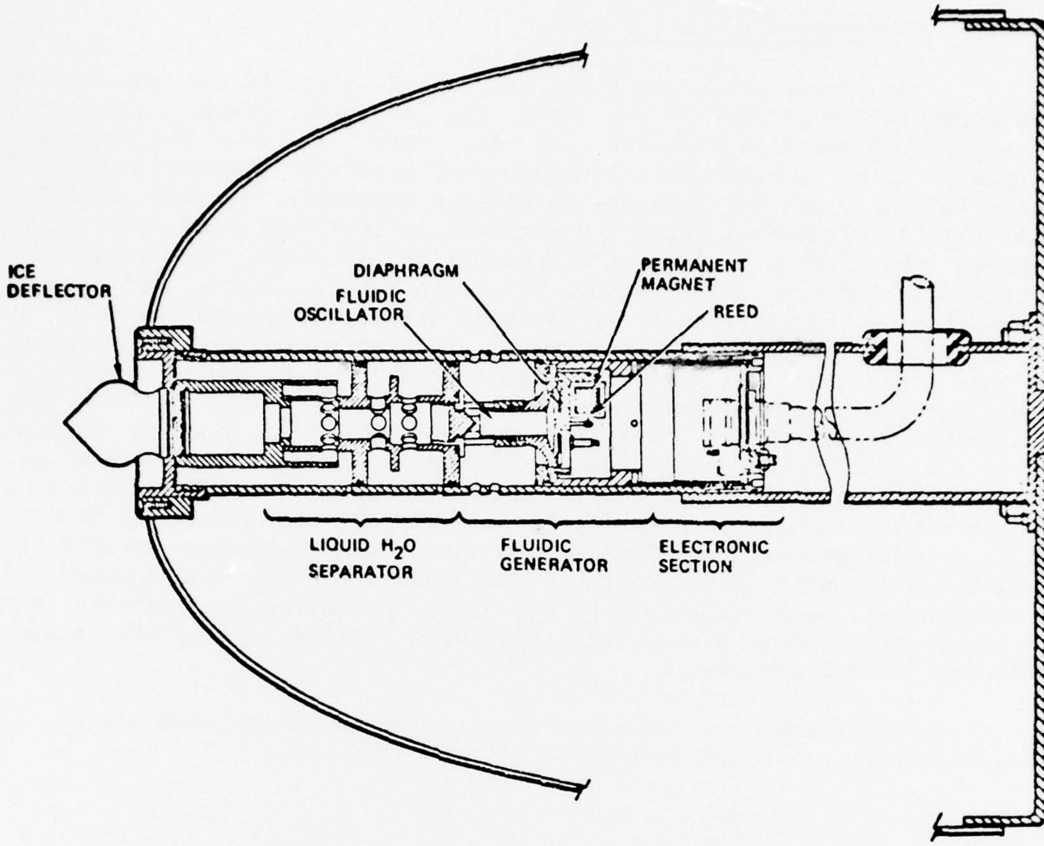

Figure 9. Airspeed actuated safety and arming device.

front portion of the deflector. As the ice thickens, it cannot turn sharply around the deflector's back surface and is thus expelled in the free stream. This expulsion prevents ice formation and accumulation on the screen entrance of the housing. The effectiveness of the ice deflector was established in icing condition tests (sect. 5.3). After passing the deflector, the air then passes through a screen at the entrance of the housing, and residual solid particles are ejected by pressure forces through side vents along the housing body. Water droplets in the air also are separated and forced through the drain holes while the air makes two 180-deg turns before entering the generator nozzle. The two-stage water-air separator is similar to one developed after tests conducted under rain and icing condition simulation.[3]

[3]*C. J. Campagnuolo and F. Villarroel, Fluidic Generator System to Environmentally Fire Aircraft Rockets, Harry Diamond Laboratories TR-1448 (May 1969).*

4.3 Electronic Circuit of AASAD

The electronic circuit in the AASAD (fig. 10) is operated by two inputs: One is the 28 Vdc from the aircraft power supply upon activation of the firing switch, and the other is from the generator output. This circuit (1) eliminates any residual voltage generated below 140 knots and (2) provides an all-arm condition at 170 KIAS for all flight altitudes. When the aircraft is in flight and the pilot presses the firing switch at a speed below 140 KIAS, any output is directed to the base of transistor Q_1, which remains in the off state. Transistor Q_2, normally in the conducting state, causes transistor Q_3 to be off. This state keeps the SCR Q_4 at a ground potential. The circuit in this state does not activate the intervalometer, and no cartridges are ejected. When the aircraft reaches a velocity of 170 KIAS, the generator output becomes sufficient to cause Q_1 and Q_3 to conduct and Q_2 to cut off. Thus, a positive voltage is placed at the gate of Q_4. With the circuit in this mode, the pilot presses the firing switch; a 28-Vdc signal from the aircraft power supply is supplied to the SCR anode, causing the intervalometer to step and dispense cartridges. Variations in output from generator to generator are compensated by potentiometer R_7 at the base of Q_1. The potentiometer adjusts the voltage level needed at Q_1; this adjustment allows a uniform arming velocity for all systems.

The circuit is packaged in a container and mounted behind the fluidic generator in the protective housing (fig. 11).

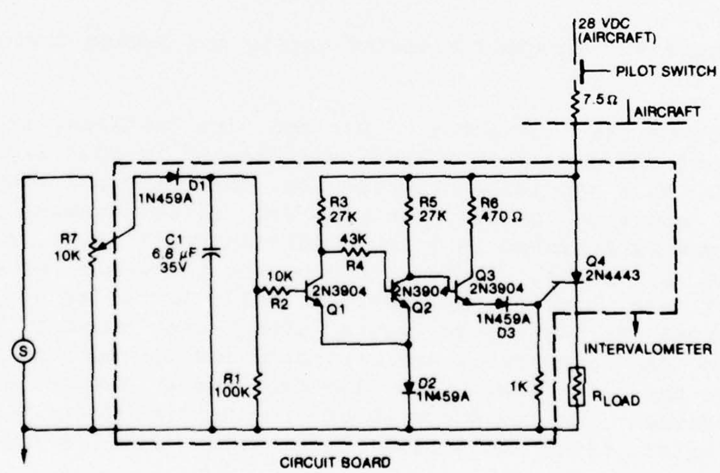

Figure 10. Firing circuit of airspeed actuated safety and arming device.

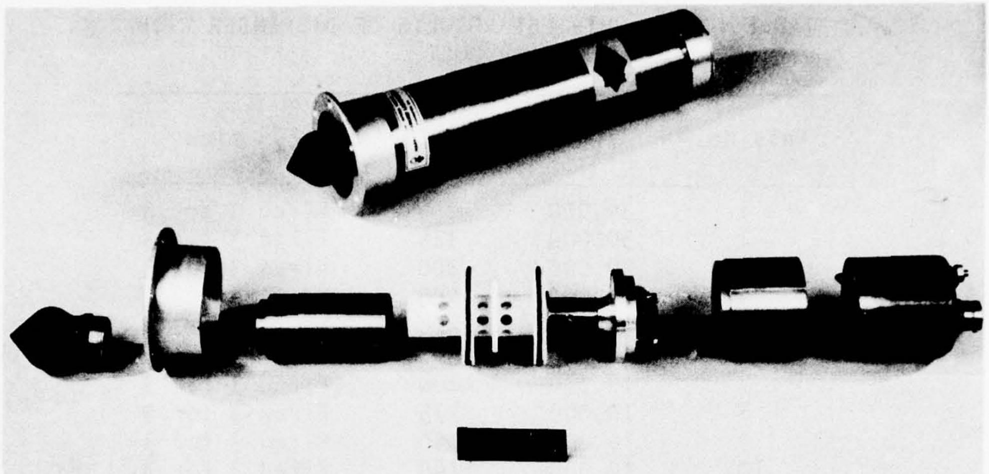

Figure 11. Components and assembled view of airspeed actuated safety and arming device.

5. FLIGHT TESTS

5.1 Functional Flight Tests

The AASAD was designed and fabricated at HDL under the sponsorship of NWC. The in-flight tests were conducted by NWC at China Lake.[4] For these tests, the dispenser loaded with flares was flown on an A-4 aircraft. The dispenser also contained a telemetry system which monitored the generator output voltage. At a given altitude and speed, when the pilot pressed the firing switch, flares were ejected and the generator voltage was measured. In the initial flight tests, the AASAD was positioned at the aft section of the dispenser under the fin to protect the air intake from possible physical damage during handling. Telemetered data obtained during flight indicated that the generator output was insufficient to activate the AASAD firing circuit, due to flow separation at the aft section of the dispenser. To increase the flow inlet to the generator, a metal duct was mounted on the side of the dispenser. The duct was designed to gather air flow at the nose section and pass it to the generator at the aft section. Flight tests conducted with this configuration indicated that the AASAD should be in the forward section of the dispenser (table I). Figure 12 shows the AASAD

[4]*H. S. Duff, Engineering Development Summary for Dispenser, Cartridge, SUU-53/A, Naval Weapons Center TP5631, China Lake, CA (May 1974).*

TABLE I. FLIGHT-TEST RESULTS OF DISPENSER WITH EXTERNAL AIR DUCT

Pass No.	Altitude (ft)	Velocity (KIAS)	Function
1	34,000	250	Fired 3 for 3
2	30,000	325	Fired 3 for 3
3	20,000	300	Fired 3 for 3
4	10,000	450	No fire
5	10,000	400	No fire
6	10,000	300	No fire
7	10,000	200	Fired 3 for 3
8	10,000	175	Fired 3 for 3
9	10,000	150	Fired 3 for 3
10	10,000	140	Fired 3 for 3
11	10,000	130	Fired 3 for 3

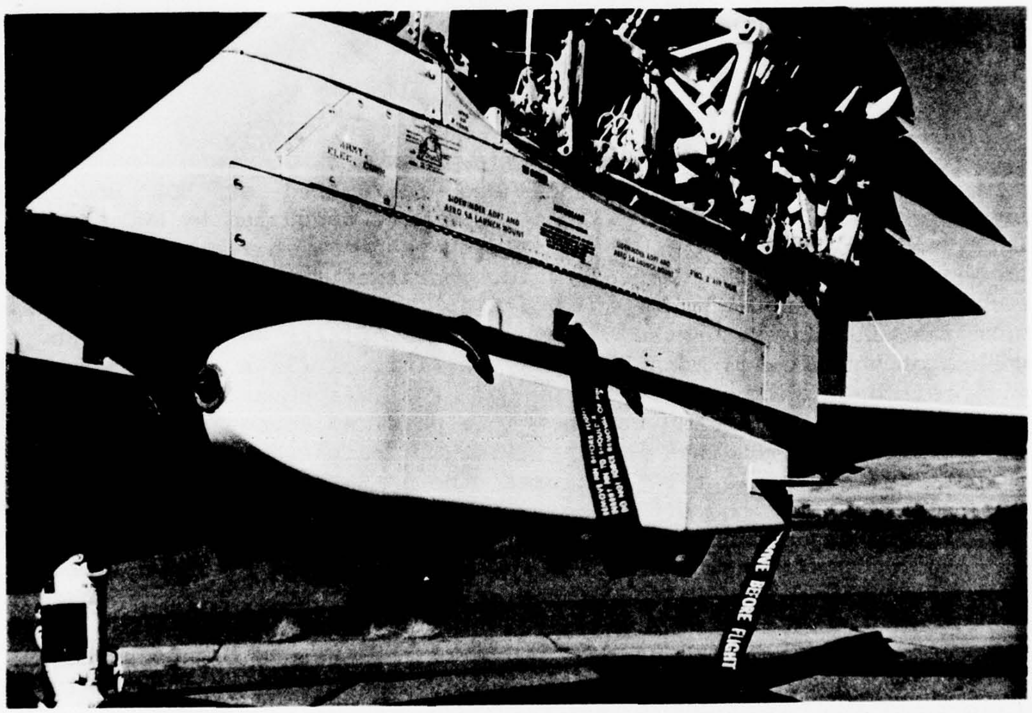

Figure 12. Final configuration of SUU-53/A cartridge dispenser with airspeed actuated safety and arming device installed at nose of dispenser.

located in the nose section of the dispenser, and table II lists additional flight-test conditions and results. At 10,000 ft (3000 m), the AASAD functioned from 160 to 395 KIAS, but not at 150 KIAS. At 20,000 ft (6000 m), 31,000 ft (9300 m), and 35,000 ft (10,500 m), the functional velocities were 295, 350, and 250 KIAS, respectively.

A series of flight tests also was conducted with an A-6 aircraft to verify the speed range at which the AASAD would function. From the tests, it was observed that the AASAD was as stable on the A-6 as on the A4 aircraft. Some variation was noted in the speed range where the no-fire and all-fire conditions occurred. These variations, however, were small, and the range of the all-fire condition was attained at 170 KIAS. This range gives a nominal 160 ± 10 KIAS threshold, which is less than 7-percent tolerance.

TABLE II. FLIGHT-TEST RESULTS WITH AIRSPEED ACTUATED SAFETY AND ARMING DEVICE INSTALLED AT NOSE OF DISPENSER

Pass No.	Altitude (ft)	Velocity (KIAS)	Function
1	35,000	250	TM[1] indicated 3 for 3
2	31,000	350	TM indicated 3 for 3
3	20,000	295	TM indicated 3 for 3
4	10,000	479	TM indicated 3 for 3
5	10,000	395	TM indicated 3 for 3
6	10,000	300	TM indicated 3 for 3
7	10,000	200	TM indicated 3 for 3
8	10,000	180	TM indicated 3 for 3
9	10,000	150	No fire
10	10,000	165	TM indicated 3 for 3
11	10,000	155	TM indicated 2 for 3
12	10,000	160	TM indicated 3 for 3

[1]*TM: telemetry data.*

5.2 Supersonic Flight Tests

The ability of the AASAD to survive supersonic flights and still function as designed was successfully demonstrated on an F-4B aircraft. The plane was flown at supersonic speeds dispensing WMU-1 catalyst cartridges. The maximum speed attained by the aircraft was 650 KIAS (Mach 1.4) at 25,000 ft (7500 m). Then the cartridges were fired at 550 KIAS (Mach 0.9) at 5000 ft (1500 m).

5.3 Icing-Condition Tests

Flight tests of the AASAD in icing conditions were conducted by NWC.[4] A bell-shaped deflector protruded in front of the air intake (fig. 13). The deflector deflects ice and water particles outside the

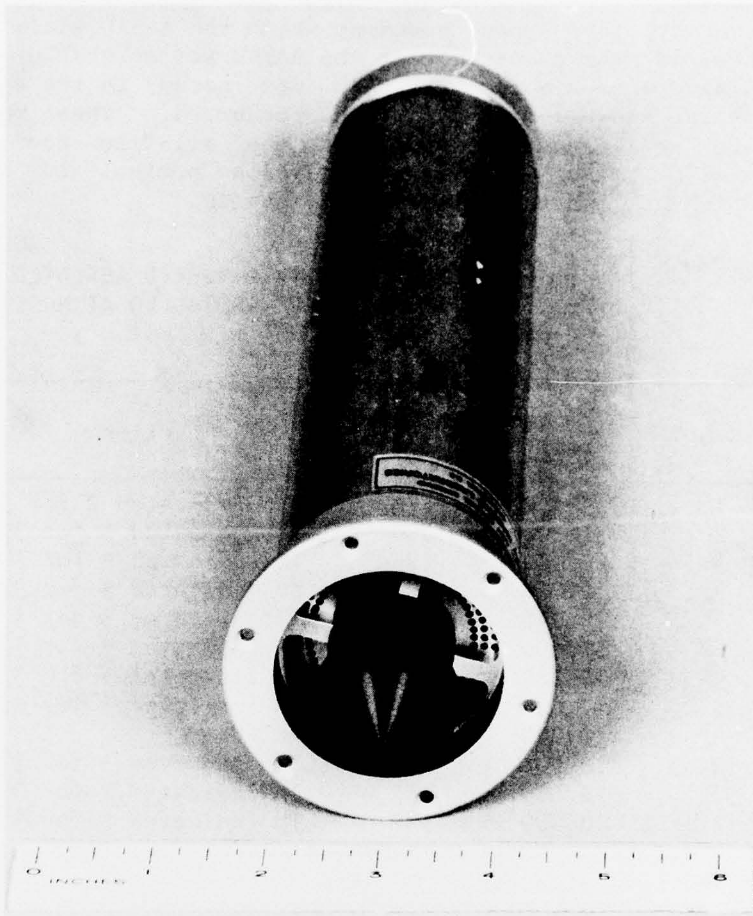

Figure 13. Ice deflector in airspeed actuated safety and arming device.

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[4] *H. S. Duff, Engineering Development Summary for Dispenser, Cartridge, SUU-53/A, Naval Weapons Center TP5631, China Lake, CA (May 1974).*

periphery of the air intake screen and still allows the air to flow freely through the screen to the generator. During the initial flight test in an icing condition, approximately 1/4 in. (0.635 cm) of ice buildup was noted on the deflector and around the air intake, but photographs showed that the air intake screen remained ice free; thus the firing circuit functioned normally. However, the icing conditions during this test were believed to be not severe enough to prove conclusively that the deflector was 100-percent effective, so an additional flight test was conducted.

In this test, 1/2 in. (1.27 cm) of ice was built up on the deflector and on the periphery of the intake screen, but the screen remained ice free. The dispenser was mounted on a front station of a multiple-ejection rack, and the pilot was able to see the air intake screen and visually verify that it was free of ice when the buildup was heaviest around the screen and on the deflector. Cartridges were fired with complete success during these conditions (table III).

TABLE III. FLIGHT-TEST RESULTS IN ICING CONDITIONS

Pass No.	Altitude (ft)	Velocity (KIAS)	Function
1	13,000	250	Fired 2 for 2
2	11,000	140	No fire
3	12,000	160	No fire
4	15,000	200	Fired 2 for 2
5	15,000	160	No fire
6	15,000	180	Fired 2 for 2
7	13,000	250	Fired 5 for 5

6. OPERATIONAL EVALUATION OF COLD CLOUD MODIFICATION SUBSYSTEM

The operation of the Cold Cloud Modification Subsystem was evaluated at NWC in August and September 1975. The objectives were as follows:

a. To determine the ability of the dispenser to dispense weather modification usage (WMU) series catalyst generators from A-6 aircraft throughout the operational envelope of the dispenser from 170 KIAS to Mach 0.9 at altitudes to 35,000 ft (10,500 m).

b. To assess the reliability of the SUU-53/A.

There were two major results:

a. The dispenser operated properly from 170 KIAS to Mach 0.84 (maximum velocity achieved) at altitudes to 20,000 ft (6000 m). Between 20,000 and 35,000 ft (6000 and 10,500 m), the AASAD threshold airspeed needed for operating (arming velocity) increased to 240 KIAS.

b. When the dispenser was carried next to a multiple ejector rack (MER) on an adjacent aircraft wing station, the reliability of the dispenser was substantially reduced from 20,000 to 35,000 ft (6000 to 10,500 m) at Mach 0.75 and above.

By the limited testing, the dispenser was evaluated as operationally effective when not carried next to another store and when used at airspeeds above the 240 KIAS threshold airspeed. The higher airspeed of 250 KIAS at altitudes above 20,000 ft (6000 m) is not considered detrimental to mission accomplishment by the A-6 aircraft, especially since seeding normally does not require operations at altitudes above 20,000 ft (6000 m). Nevertheless, the higher airspeed may be a factor for other types of aircraft with lower operating airspeeds.

The Operational Evaluation of the Cold Cloud Modification Subsystem (Project O/V 122) Final Report recommended that the dispenser be approved for service in the testing of seeding effectiveness. However, further definition of the operational envelope was recommended prior to approval for general-purpose use.

7. DESIGN IMPROVEMENTS AND FINAL OPERATION FLIGHT-TEST SUMMARY

7.1 Design Modification

To expand the operational envelope of the dispenser and to remove the operational constraints, the AASAD design was modified further.

As discussed in section 4.3, the variations in fluidic generator output voltage from unit to unit are compensated by the potentiometer, which is designed to match the output impedance of the generator with that of the electronic firing circuit at selected arming velocities. An overall increase in the output voltage from the generator can be obtained by adjusting the potentiometer when the AASAD threshold arming velocity is decreased. It is decreased when the generator output impedance is lowered to values approaching the value of the generator coil. In general, in the laboratory, the generator output voltage increased as the output impedance decreased. Figure 14 shows the output obtained from an AASAD unit adjusted at three different threshold arming velocities. By lowering the threshold arming velocity

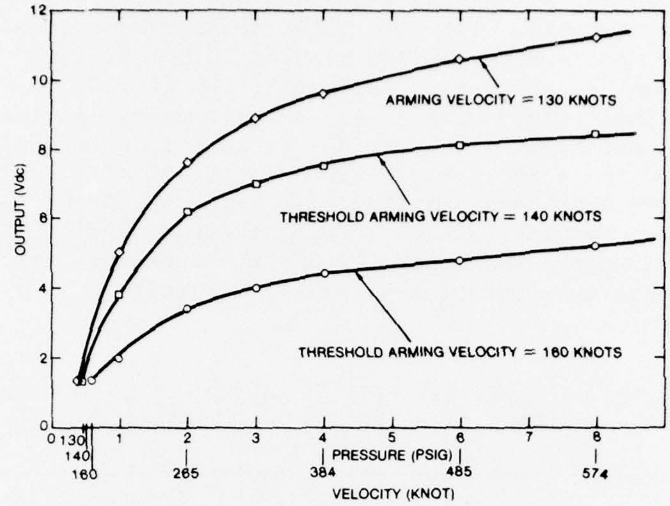

Figure 14. Output voltage of airspeed actuated safety and arming device for three different values of threshold arming velocities.

in the laboratory to 130 knots, the output voltage rise is about 2.5 times that obtained at 160 knots, the original threshold arming velocity. This increased output is expected to compensate for the voltage losses at higher altitudes (20,000 to 35,000 ft--6000 to 10,500 m) and from flow interference caused by the MER store. Analysis of the qualification-evaluation-tests results indicates that at 35,000 ft (10,500 m) and with the MER store at an adjacent station, the AASAD experienced a loss in output voltage of approximately 60 percent. Hence, by choosing the threshold arming curve (fig. 14) for 130 knots, a no arming at 140 KIAS and an all arming at 170 KIAS should be obtained in flight.

7.2 Final Flight Tests Summary

The readjusted AASAD was flight tested at NWC in January 1976. For these tests, the arming velocity requirements were redefined to no arming at 140 KIAS and below and all arming at 170 KIAS and above.

Flight tests were first conducted aboard an A-4 aircraft. A dispenser was positioned adjacent to an MER rack and tested at altitudes from 10,000 to 35,000 ft (3000 to 10,500 m). As in the project O/V 122 tests, the pilot attempted to fire three cartridges from the dispenser. Successful firings were recorded at each 5000-ft (1500-m) increment at

170 and 280 KIAS for all-arming tests and at 10,000 ft (3000 m) at 140 KIAS for no-arming tests. Two more AASAD units were successfully tested without MER for no arming at 140 KIAS at 10,000 ft (3000 m) and all arming at maximum A-4 aircraft speed at 35,000 ft (10,500 m). The same two units were then tested aboard an A-6 aircraft. As table IV shows, no arming was observed at 140 KIAS at altitudes of 12,000, 20,000, 30,000 or 35,000 ft (3600, 6000, 9000, or 10,500 m). Full arming took place between 170 KIAS and maximum aircraft speed at each of the altitudes. The results clearly demonstrated the ability of the dispenser to dispense WMU series catalyst generators throughout the entire operational envelope of A-4 and A-6 aircraft.

TABLE IV. FLIGHT-TEST RESULTS OF SUU-53/A CARTRIDGE DISPENSER ON BOARD A-6 AIRCRAFT

Pass No.	Altitude (ft)	Velocity (KIAS)	Function	
			Station L	Station R
1	12,000	140	0 for 3	0 for 3
2		170	3 for 3	3 for 3
3		230	3 for 3	3 for 3
4		310	3 for 3	3 for 3
5		400	3 for 3	3 for 3
6	20,000	140	0 for 3	0 for 3
7		170	3 for 3	3 for 3
8		210	3 for 3	3 for 3
9		260	3 for 3	3 for 3
10		740	3 for 3	3 for 3
11	30,000	140	1 for 3	0 for 3
12		170	3 for 3	3 for 3
13		210	3 for 3	3 for 3
14		260	2 for 2	1 for 1
15		310	2 for 2	1 for 1
16	35,000	140	0 for 3	0 for 3
17		170	3 for 3	3 for 3
18		230	3 for 3	3 for 3
19		260	3 for 3	3 for 3
20		280	3 for 3	3 for 3
21		300	3 for 3	3 for 3

8. ENVIRONMENTAL-TESTING SUMMARY

Eight AASAD units were installed in dispensers and subjected to an environmental-qualification program as prescribed[5] in NWC Memorandum Regulation 4533-31-72. Testing was conducted at NWC, China Lake; Naval Missile Center, Fort Mugu, CA; and Ogden Technology Laboratory, Fullerton, CA, under the cognizance of NWC from June 1972 to December 1973.

Figure 15 shows the sequence during the testing program. Performance tests were conducted after each environmental test, and functional tests were conducted as required under environmental conditions. The environmental testing included these tests:

a. Temperature: Dispensers were subjected to a low-temperature environment of -60°F and a high-temperature environment of +160°F.

b. Shock: Dispensers were subjected to vertical shocks of 50 g and corner drops of (average) 7.3 g in the vertical axis, 2.9 g in the longitudinal axis, and 5.7 g in the transverse axis.

c. Thermal shock: Dispensers were subjected to temperature cycling from +140 to -60 to +140°F.

d. Vibration: Dispensers were subjected to sinusoidal vibration at controlled temperatures of -40 and +125°F.

e. Salt fog: Dispensers were subjected to salt spray of 5-percent salt/95-percent water for 48 hr.

f. Sand and dust: Dispensers were subjected to a dust concentration of 0.3 ± 0.2 g/ft^2 (3.22 ± 2.05 g/m^2) at a velocity of 1750 ± 250 ft/min (525 ± 75 m/min) for 6 hr.

In addition, the fluidic generator was subjected to design verification tests in which the generator was tested in air-flow conditions for 800 hr without failure. This is four times the expected utilization time.

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[5] *Test Procedures for Environmental and Safety Testing of the Dispenser, Cartridge, SUU-53/A, Naval Weapons Center Memorandum Regulation 4533-31-72, China Lake, CA (February 1972).*

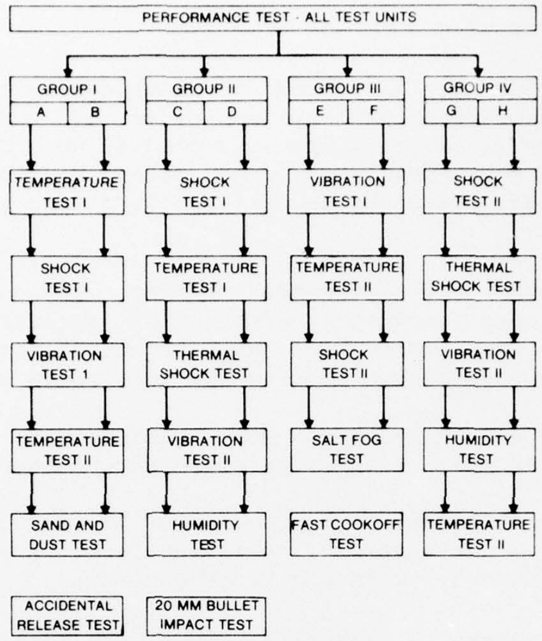

Figure 15. Final test phase of SUU-53/A cartridge dispenser.

The AASAD units successfully passed all of these tests including functional test and postperformance tests.[6]

9. RELIABILITY ANALYSIS

Studies were conducted by NWC for the Naval Air Systems Command on the reliability of the fluidic generator and its related electronics for the dispenser.[7] The analyses were based on the mission profile, which consists of two modes: (1) the dormant mode, in which 300 dispensers are in depot storage (8760 hr/yr), and (2) the operational mode, in which 100 dispensers are in 10 missions of which less than 20 hr/yr

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[6] *J. L. Halpin, Environmental and Safety Testing of the Dispenser Cartridge, SUU-53/A, Naval Weapons Center, China Lake, CA (March 1974).*

[7] *Fluidic Generator Reliability Analysis, Naval Weapons Center TN-556-73-5, China Lake, CA (August 1973).*

(2 hr per mission) is spent in flight. For the dispenser and fluidic generator, table V shows the predicated failure rates (the number of catastrophic failures in a given unit of time--10^6 hr) in the dormant and operational modes.

TABLE V. PREDICATED FAILURE RATES

Environment	Failure rate		
	Dispenser ($\times 10^{-6}$)	Fluidic generator ($\times 10^{-6}$)	Total ($\times 10^{-6}$)
Depot storage	0.436	0.0763	0.5123
Shipboard storage	0.703	0.296	0.999
Powered flight[1]	15.96	53.869	69.829
Captive flight[2]	4.85	44.769	49.619

[1]*During cartridge dispensing (full 28 Vdc applied to airspeed actuated safety and arming device).*
[2]*During absence of full power.*

Table VI summarizes the fluidic generator's predicted reliability, defined as the probability (expressed as a portion of unity) that the fluidic generator will successfully complete its defined missions in the time period specified.

TABLE VI. PREDICTED RELIABILITY OF FLUIDIC GENERATOR AND DISPENSER

Component	Composite failure rate[1]					Flight operational failure rate[2]	Composite[3]	Reliability of flight operation[4]	
	Failures/hr (1 unit)	Failures/month (400 units)	Failures/month (120 units)	Failures/10 yr (400 units)	Failures/10 yr (120 units)	Failures/hr (1 unit)	Per life cycle (1 unit)	For 2-hr mission (1 unit)	For 100 missions (1 unit)
Fluidic generator	0.157×10^{-6}	0.46	0.030	5.50	3.6	44.84×10^{-6}	0.986	0.99991	0.9911
Dispenser	0.505×10^{-6}	0.147	0.058	17.70	7.0	4.94×10^{-6}	0.957	0.99999	0.9990
Fluidic generator and dispenser	0.662×10^{-6}	0.194	0.088	23.20	10.6	49.78×10^{-6}	0.943	0.99990	0.9901

[1]*High-quality components are assumed in computing failure rates.*
[2]*Weighted for the time ratio of captive versus powered flight.*
[3]*The probability that a single unit will not fail in any environment over the life cycle (87,600 hr).*
[4]*The probability that a single unit will not fail at any time during a flight.*

DEFINITIONS:

Composite failure rate: *weighting of dormant failure rate and operational failure rate by quantity of dispensers held or operated in each of these conditions.*
Flight operational failure rate: *time weighted average rate applied to environment of captive and powered flight.*

10. CONCLUSIONS

The feasibility of the fluidic generator as an airspeed actuated safety and arming device for the SUU-53/A dispenser has been clearly demonstrated in the field. The device prevents accidental ground firing of cartridges and provides an arming signal only when the aircraft is in flight. The advantages of the fluidic generator are the high reliability inherent in minimal moving parts and the ability to withstand adverse operating and storage environments. The dispenser was given final Hazardous Exposure of Radiation to Ordnance (HERO) safety certification by the Naval Weapons Laboratory, Dahlgren, VA, in February 1974. The AASAD was type classified for unlimited production in May 1975. It has successfully passed all flight-qualification tests aboard A-4, A-6, and P-3 aircraft.

ACKNOWLEDGEMENT

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